APPLICATION

for

AUTHORITY TO CONSTRUCT

GEOTHERMAL WELLS

Kilauea Middle East Rift Zone

Estate of James Campbell Property TMK 1-2-10:3

True/Mid-Pacific Geothermal Venture

September, 1988

Encl (2) to LTR to
Director, Health Dept.

EXHIBIT "DD"

~~September 1~~, DECEMBER 17, 1988

Director of Health
Hawaii State Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

SUBJ: APPLICATION FOR AUTHORITY TO CONSTRUCT GEOTHERMAL EXPLORATION WELLS

REF: (a) Board of Land and Natural Resources Decision and Order of April 11, 1986, in the matter of the Conservation District Use Application of the Estate of James Campbell (CDUA No. HA-12/20/85-1830)

(b) Hawaii Administrative Rules, Title 11, Department of Health, Chapter 60, "Air Pollution Control"

1. In accordance with reference (a), a permit was issued to Estate of James Campbell, in turn assigned to True/Mid-Pacific Geothermal Venture, authorizing geothermal development activities to be conducted along a segment of the Kilauea east rift zone, Puna District, Island of Hawaii, TMK 1-2-10:3. The Decision and Order authorized exploration and development of geothermal resources to a level that would produce 100 MW of geothermal generated electricity.

2. Development will progress incrementally beginning with the exploration phase on which this authority to construct application is based. This exploration phase will consist of the sequential drilling of up to 12 deep wells over a period of 20-24 months. Each successful well will be vented to the atmosphere (unabated) for up to 8 hours to clear the well bore, and subsequently flow-tested for 30-45 days using appropriate pollutant and noise abatement systems.

3. The potential environmental impacts for the project were presented in (1) the Revised Environmental Impact Statement for Kahauale'a, June 1982; (2) the Final Supplemental EIS to the Revised EIS for Kahauale'a, February 1986, which included the results of air quality monitoring and air dispersion modelling; and (3) during five contested case hearings on the project since 1982. These contested hearings resulted in an extensively detailed public record concerning all aspects of geothermal development with particular emphasis on the potential impacts on ambient air quality and noise levels and the influence of project site meteorological conditions on these impacts. A summary report of prior air quality and meteorological monitoring for the Kilauea east rift zone was prepared for the State (DBED, July 1985). An executive summary of this report is appended as Attachment 1.

4. This application for authority to construct, Forms AS-P-1 and AS-P-2 (Attachment 2), is submitted in accordance with reference (b) and is limited to individual geothermal exploration wells which are planned to be drilled sequentially at the approximate locations of the sites shown in Figure 1. Supplemental data in support of the application for authority to construct is contained in Attachment 3.

5. Prior to a geothermal well being part of a distribution system to supply geothermal resources to a power plant, emissions will occur only during drilling operations and during testing of each successful well after which the well will be shut-in until it can be connected (via distribution pipeline) to a power plant. A geothermal well will be "operated" only as part of a power generating system. After a successful well is completed, tested and shut-in, the emission abatement system used during drilling and testing is removed and installed at the next drill site.

6. It should be noted that any power plants that may be constructed will incorporate the design features and/or emission abatement systems necessary to limit and control emissions from the geothermal resources of all wells supplying a particular power plant. In this context, a geothermal well constitutes a temporary, time-limited, quantity-limited emission source during "construction." Subsequently, when the well is produced ["operated"], it is an integral part of the power plant(s) which becomes the combined "source" of the emissions from each of the wells supplying the plant. Any subsequent application for authority to construct a geothermal power plant will contain the combined data on emissions from all wells to be operated

and the abatement system that will be installed in the power plant. If the power plant generating system is disrupted or fails, the emission "source" would continue to be the power plant facility where the steam flow would by-pass the generator into the abatement system which would continue in operation until the power plant is returned to full operation. If both plant and abatement systems at the power plant fail, the steam flow from "operating" geothermal wells supplying the plant could be directed to the back-up abatement system, or the wells could be shut-in if exceedence of ambient air standards would otherwise occur. Air quality monitoring of power plant emissions in maximum impact areas as predetermined from data obtained during the exploratory phase would detect any deteriorating levels of air quality which threaten or violate NAAQS or State standards.

7. The information supporting the application is based on data requirements of Sub-Chapter 3 of reference (b) in that the emissions from individual geothermal wells under "construction" (during which drilling operations, venting and abated flow testing occur) do not constitute a "major stationary source" that would qualify the application for a prevention of significant deterioration (PSD) review as prescribed in Sub-Chapter 4. The "source" during construction or subsequently, during "operations" as part of a power plant, is not one of the 28 named source categories listed in Section 169 of the Clean Air Act that emits 100 tons per year of a pollutant regulated by the Act, nor, as an unlisted "Stationery source" does it emit 250 tons per year of a pollutant regulated by the Act.

8. Source Description

   a. The principal source for the emissions during the construction of exploration wells is the geothermal fluid released from the well during drilling, venting and flow testing. The emissions from the geothermal resources are expected to be present as (1) dissolved solids in the geothermal brine and (2) in non-condensable gases from the steam portion of the resource. The estimated concentrations of gases and dissolved solids expected to be present in the geothermal steam and brine are tabulated in Attachment 3 which contains supplemental data in support of this application.

   b. The principal pollutant in the geothermal fluid to be controlled is hydrogen sulfide. Other minor sources of emissions (nitrogen oxides, carbon monoxide, hydrocarbons and sulfur dioxide) are from the exhausts from the drilling rig equipment (motors, compressors and portable generators) during the drilling of the well. These sources consist of three 700-HP diesel engines to power the rig draw works and mud pumps, two 300-KW diesel electrical power generators and three 700-HP diesel engines to power air compressors to be used during a portion of the drilling. These mobile, internal combustion units are temporary sources which will not be a part of any stationery source. Total estimated emissions from these temporary sources would amount to approximately two tons per well drilled to 8,000 ft. There will also be fugitive emissions from road and site dust for which there are no analytical data.

c. Emissions from geothermal resources will occur only: After (1) a geothermal reservoir is intersected by the drill bit during the last 15-20 days of drilling each well to a depth of approximately 8,000 ft., (2) during venting of the completed well for a period up to 8 (daylight) hours, and (3) during flow testing of the well for periods of 30-45 days.

d. A plot plan of the drill site showing all operating equipment and relative spatial arrangement is outlined in Figure 2.

9. The applicant, by signature hereon, assumes responsibility for the construction of the above described geothermal wells in accordance with Chapter 11-60, Hawaii Administrative Rules, and such permit conditions as may be prescribed by the Director.

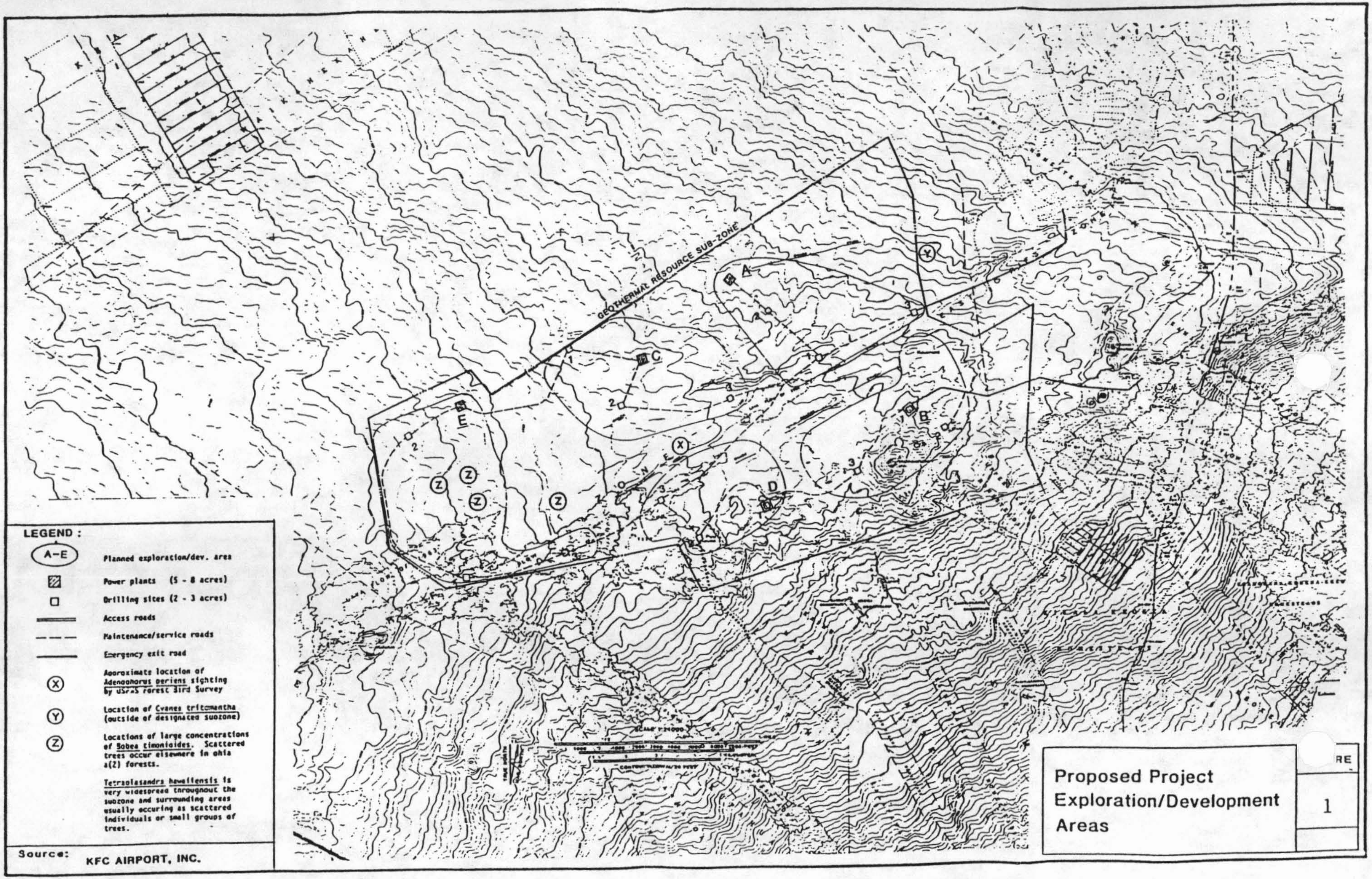
10. A filing fee of $50 is included as Attachment 4.

Very truly yours,

TRUE GEOTHERMAL ENERGY CO.
(OPERATOR FOR TRUE/MID-PACIFIC GEOTHERMAL VENTURE)

H.A. True, III
Partner

Attachments:
1. Executive Summary of Report on Baseline Air Quality and Meteorological Conditions, Kilauea East Rift
2. Authority to Construct Forms, AS-P-1 & AS-P-2
3. Supplemental data
4. Check for filing fee



Source: KFC AIRPORT, INC.

RE 1

Proposed Project Exploration/Development Areas

1. Exploration Program

A. Overview of Geothermal Resource Exploration and Development.

Inasmuch as the location of geothermal reservoirs must be determined by deep exploratory drilling and since the economic producibility of the resource from each discovered reservoir can only be determined by testing each successful well, the drilling sites selected, as shown in Figure 1, except for site A1, are tentative. The exact location of other drilling sites will depend upon previous drilling results and testing. The final surveyed location of each well to be drilled will be provided after each survey is completed.

For planning purposes, five exploration/development (E/D) areas have been selected. Each area has three primary drilling sites planned (for a total of 15 sites) connected by access/service roads. Allowing for estimates of reserve and non-producible wells, a total of 35 individual wells may have to be drilled within the 5 E/D areas to produce 100 MW of electricity as authorized under the Conservation District Use Permit for the project. If directional drilling is technically and economically feasible, up to 6 exploration/development wells may be drilled from one drilling site.

B. Exploratory Drilling Plan.

The first drilling site, True/Mid-Pacific A1, Figure 1, is planned near the eastern area of the proposed sub-zone, north of the rift zone center in E/D area "A". The general sequence of exploration drilling is as follows:

1) If the first exploration well in E/D areas "A" is successful, a second well will be drilled in this area to obtain indications of

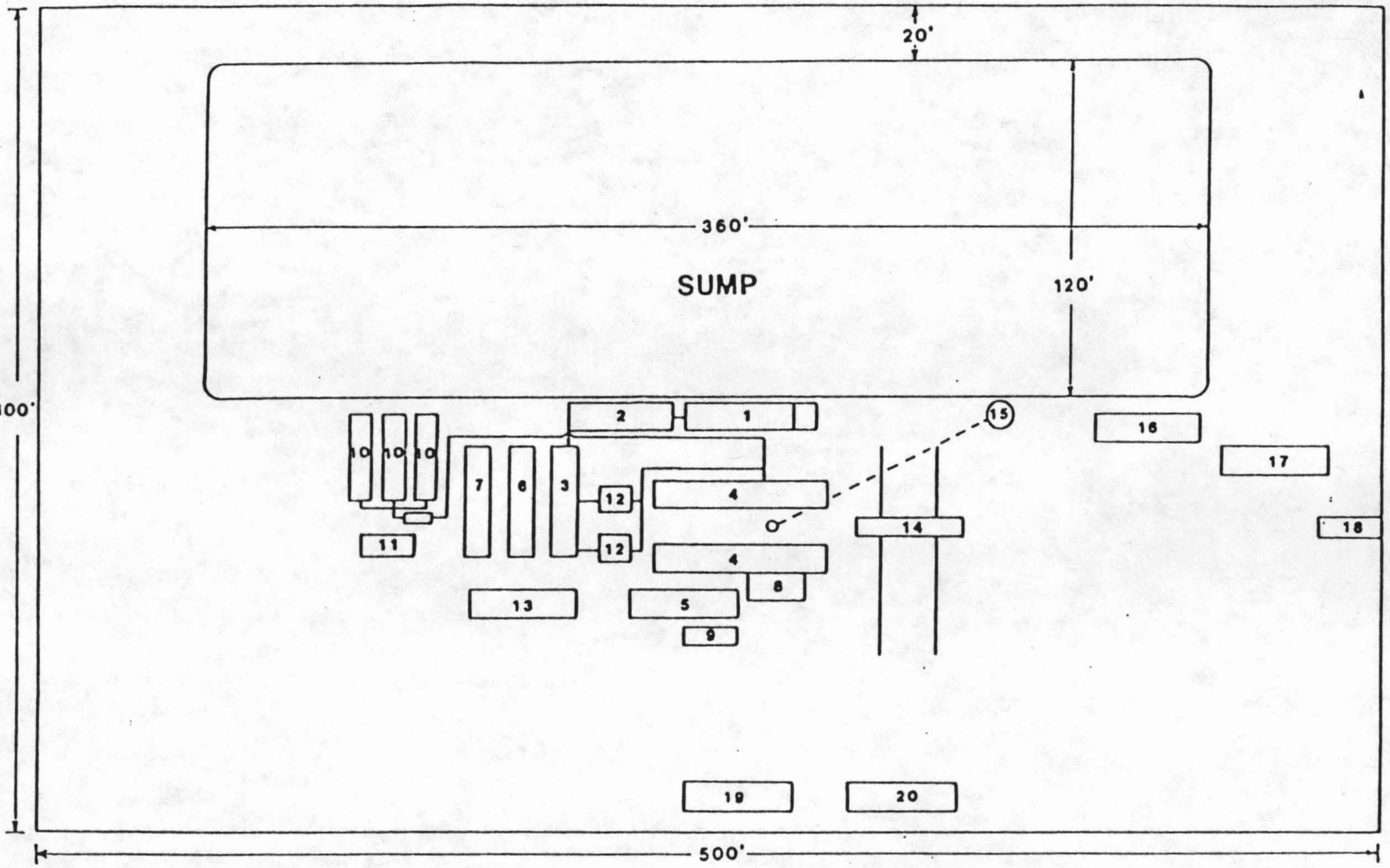
the northern boundary of the discovered reservoir. (A "successful" well is one from which geothermal resources can be produced economically.) Regardless of the results of the second well the next exploration well would be drilled in E/D area "B", at or near one of the three planned sites.

2) If the first exploration well in E/D area "A" is not successful, the second well will be drilled at or near one of the three sites in E/D area "B" on the south side of the rift zone center near Pu'u Heiheiahulu.

3) If the first well in E/D area "B" is successful, another exploration well would be drilled at one of the other planned locations within E/D area "B". If the first well in this area is unsuccessful, the next well would be drilled at or near one of the three sites in E/D area "C", on the north side of the rift zone center.

4) If the first well is unsuccessful in E/D area "A" and E/D area "B", a decision would be made to move to E/D area "E", in the western portion of the GRS near the more active section of the rift zone. If a well drilled at E/D area "E" is also unsuccessful, the project exploration strategy would be re-evaluated.

5) If a successful well is drilled in E/D area "C", the next wells would be drilled in E/D area "D" and then "E".



1. Mud tank with slug pit
2. Mud tank
3. Mud tank
4. 2-Subbases
5. Generator house
6. Water tank
7. Fuel tank
8. Dog house
9. Accumulator
10. 3-Air compressors for air drilling
11. Compressor operator's trailer
12. 2-Mud pumps
13. Cementing unit
14. Cat walk with pipe racks
15. Muffler for air drilling
16. Abatement equipment
17. Mud logger's trailer
18. Electric logging unit
19. Part house/change room
20. Tool pushers' trailer

TSI
THERMASOURCE

PLOT PLAN
(True/Mid-Pacific Project)

Figure 2

Application No. A-______

Department of Health
State of Hawaii

Environmental Protection and
Health Services Division
Environmental Permits Branch

FORM AS-P-1

GENERAL APPLICATION FOR AUTHORITY TO CONSTRUCT OR MODIFY A FACILITY

(See Attached Instructions)

I. General Information

A. Applicant (Authority to Construct to be issued to)

1) Name TRUE GEOTHERMAL ENERGY CO.

895 West River Cross Road

2) Mailing Address P.O. Box 2360
(Number) (Street)

Casper Wyoming 82602
(City) (Island) (Zip)

3) Contact Person 1) Rod Moss, Mid-Pacific Geothermal, Inc.
2) Allan Kawada, True Geothermal Energy Co.

Title 1) Vice President 2) Hawaii Representative

Phone 1) 808 521-9004 2) 808 528-3496

B. Representative Authorized to Act for Applicant

1) Name Allan Kawada

2) Address 888 Mililani Street, 8th Floor

Honolulu, Hawaii 96813

3) Contact Person

Title True Geothermal Energy Co.
Hawaii Representative

Phone 808 528-3496

C. Nature of Business of Applicant

Exploration and Development of Geothermal Resources

D. 1) Equipment Description

Stack No. [1/]	Unit No [2/]	Equipment	Fuel	Equipment Location Address & TMK	UTM Coordinates Zone	East	North
1A	1A	Cyclone Separator Discharge for drilling fluid discharge	Geo.Steam & Brine	Puna District, Island of Hawaii, TMK 1-2-10:3	4		
2A	2A	Well Head Manifold During well bore cleanout (venting)	Geo.Steam & Brine	Puna District, Island of Hawaii, TMK 1-2-10:3	4		
3A	3A	Rock Muffler Discharge during well testing	Geo.Steam & Brine	Puna District, Island of Hawaii, TMK 1-2-10:3	4		

2) Air Pollution Control Equipment

Stack [3/] No.	Unit [3/] No.	Control Equipment	Pollutant Controlled
1A	1A	Sodium hydroxide injection up stream of Cyclone Separator	Hydrogen Sulfide
2A	2A	None	N/A
3A	3A	Sodium hydroxide injection up stream of Rock Muffler	Hydrogen Sulfide

Note: See specific item instructions for explanation of footnotes.

E. Does the prc ed project require a County s ial management area permit? Yes ____ No X

II. Reason for Application [check applicable box(es)]

A. /X/ New source

B. /_/ Modification of existing source

C. /_/ Change of location

D. /_/ Change in ownership

E. /_/ Equipment now operating under permit number(s) ____________

III. Proposed Timetable

A. Proposed start date of construction and/or installation

November		1988 (for first well)
(Month)	(Day)	(Year)

B. Proposed start date of operation

July		1991 (for first power plant)
(Month)	(Day)	(Year)

IV. Certification by Applicant

I, H.A. True, III (Name), Partner (Title),

certify that I have knowledge of the facts herein set forth and that the same are true and correct to the best of my knowledge and belief, and that all information not identified by me as confidential in nature shall be treated by the Department of Health as public record. I further state that I will assume responsibility for the construction or modification of the source in accordance with the Administrative Rules, Title 11, Chapter 60, Air Pollution Control, and any permit issued thereof.

Date: ____________ Signature: ____________________

Title: Partner, True Geothermal Energy Co.

DO NOT WRITE BELOW (FOR AGENCY USE ONLY)

V. Date Application Received: ____________________

IV. Received by: ____________________

VII. Application Number A-____________________

VIII. Evaluating Official: ____________________

IX. Action on Application: Approved ________ Disapproved ________

Conditional Approval ________

X. Date of Action on Application: ____________________

XI. Permit Number A-____________________

XII. Special Conditions: ____________________

XIII. Permit to Operate Approved: Yes _____ No _____ Date ____________

XIV. Permit to Operate Number P-____________________

Department of [illegible]th
State of Hawai[illegible]

[illegible]nvironmental Protection and
Health Services Division
Environmental Permits Branch

FORM AS-P-2

SUPPLEMENTAL APPLICATION FOR AUTHORITY TO CONSTRUCT OR MODIFY A FACILITY

(In Accordance with Administrative Rules, Title 11, Chapter 60, and Chapter 342, Hawaii Revised Statutes)

(READ INSTRUCTIONS BEFORE COMPLETING)

I. General Information:

A. Authority to Construct to be issued to: ______________

True Geothermal Energy Co.
(corporation, company, government agency, firm, etc.)

B. Mailing address: 888 Mililani Street, 8th Floor
Honolulu, Hawaii 96813

C. Equipment description:

	Basic Equipment	Air pollution control equipment
1.	Drilling Pad Cyclone Separator	N_aOH Injection
2.	Well Bore	None
3.	Well Pad Rock Muffler	N_aOH Injection
4.		
5.		

II. Specific Information: (Submit the required attachments only)

Required	Item
/X/	a. Attachment P-1, Location Drawing & Process Flow Diagra[m]
/_/	b. Attachment P-2, Materials Balance Data
/_/	c. Attachment P-3, Industrial Process Equipment Data
/_/	d. Attachment P-4, Combustion Unit Data
/_/	e. Attachment P-5, Incinerator Data
/_/	f. Attachment P-6, Storage Container Data
/_/	g. Attachment P-7, Air Pollution Control Equipment Data

(cont'd)

(cont'd)

Required	Item
[X]	h. Attachment P-8, Air Pollution Emission Data
[ ]	i. Attachment P-9, Particle Size Distribution Data
[X]	j. Attachment P-10, Additional information not covered by one of the above.
[X]	k. Attachment P-11, Public Interest

The information submitted on the required data sheets should be consistent with the maximum design rate or expected rate of production or operation, whichever is higher. See instruction sheet regarding confidentiality of information.

III. Certification by Applicant or Authorized Representative:

I, H.A. True, III (name), Partner, True Geothermal Energy Co. (title)

certify that I have knowledge of the facts hereby submitted and that the same are true and correct to the best of my knowledge and belief, and that all information not identified by me as confidential in nature shall be treated by the Department of Health as public record.

Date ______________________ Signature ______________________

Title ______________________

DO NOT WRITE BELOW - FOR AGENCY USE ONLY

IV. Date Supplementary Application Received: ______________________

V. Received By: ______________________

ATTACHMENT P-1

LOCATION DRAWING AND PROCESS FLOW DIAGRAM

Submit as specified.

Required

See Fig. 1 (Atachment 3) 1. An equipment location drawing must be submitted, drawn to a reasonable scale and showing the following (show North arrow and scale on drawing):

A. The property involved, and outlines and heights, widths, and lengths of all structures on it. Identify property lines plainly.

B. Location and identification of the proposed equipment on the property. Identify stack and unit numbers.

C. Location of the property and equipment with respect to streets and all adjacent property. Show the location and height, width, and length of all structures within 300 feet of the applicant's property line. Identify all structures (residences, apartments, warehouses, machine shops, etc.)

See Fig. 4&5 (Attachment 3) 2. Process Flow Diagram. Prepare and attach flow diagrams identifying all equipment used in the process. Identify by number, points where raw materials, chemicals, and fuels are introduced, where finished products are obtained, and where gaseous emissions and/or particulate emissions may be discharged. Show locations of safety valves, bypasses, and other such devices which when activated may release air pollutants to the atmosphere. On a correspondence flow diagram, identify and specify, for all equipment items, electric motor horsepower ratings and electrical energy KVA (kilovolt-ampere) ratings.

Applic on No. A-______

ATTACHMENT P-8

STACK DATA

Stack Number	1A-L	2A-L	3A-L	
Exit Directrion of Gas Stream (up, down, horizontal)	up	up	up	
Stack Height (Meters)	5m	4m	2m	
Actual Stack Flow Rate (cubic meters per second)	21.1 m^3/sec Note 1	21.1 m^3/sec	21.1 m^3/sec	
Stack Exit Temperature (°C)	100°C	100°C	100°C	
Stack Diameter (Meters) (Inside)	2	0.25	4	
Unit Numbers Corresponding to Stack Number	1A-L	2A-L	3A-L	

NOTE 1: Steam rate only; air flow rate ______, based on 100,000 lbs/hr steam.

Instructions:

1. List all stacks for which application is made. Circle the stack numbers that, for any length of time, discharge together.

2. List all units discharging through each stack. Circle the unit numbers that, for any length of time, can discharge together.

3. The stack parameters should correspond to the operating condition where all circled units for each stack are operating simultaneously, at maximum capacity of the unit. <u>All</u> units that can discharge should be included, including <u>all</u> standby, alternate, or start-up units.

4. The stack and unit numbers should correspond to those used in AS-P-1. The same numbers should be used in all future reference.

5. If combinations of different fuels are used that cause the stack data to differ, complete one column for each possible set of stack data, and identify the fuel next to the unit number.

P-10. EMISSION RATIOS

Equipment Type Drill Pad Cyclone Separator

Stack No. 1A-L Unit No. 1 Serial No. ______

Table A. Enter emission ratios before controls. Give grams of pollutant per unit of fuel burned or ton of material processed.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Fluid	metric tons per hour	400	0	0	0	0	1300 g/t
(2)								
(3)								
(4)	Estimation Method		Hawaii Geothermal Data					Hawaii Geothermal Data

Table B. Enter Emission ratios after controls.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Fluid	metric tons per hour	400					<65 g/t
(2)								
(3)								
(4)	Estimation Method		Test data from other separators					Test data from other separators

Application No. ______

P-10. EMISSION RATIOS

Equipment Type Well Head Manifold During Well Venting

Stack No. 2A-L Unit No. 1 Serial No. ______

Table A. Enter emission ratios before controls. Give grams of pollutant per unit of fuel burned or ton of material processed.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Fluid	metric tons per hour	20,000					1300
(2)								
(3)								
(4)	Estimation Method		Hawaii Geothermal Data					

Table B. Enter Emission ratios after controls.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Fluid	metric tons per hour	20,000					1300
(2)								
(3)								
(4)	Estimation Method		Hawaii Geothermal Data					Hawaii Geothermal Data

Application No. ______

P-10. EMISSION RATIOS

Equipment Type Rock Muffler During Flow Testing

Stack No. 3A-L Unit No. 1 Serial No. ______

Table A. Enter emission ratios before controls. Give grams of pollutant per unit of fuel burned or ton of material processed.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Steam	metric tons per hour	0					1300 g/t
(2)								
(3)								
(4)	Estimation Method		Test Data HGP-A					Hawaii Geothermal Data

Table B. Enter Emission ratios after controls.

	(1) Fuel or mat'l processed	(2) Units of fuel or mat'l rate	(3) Particulate	(4) SO_2	(5) NO_2	(6) HC	(7) CO	(8) H_2S
(1)	Geothermal Steam	metric tons per hour	0					< 65 g/t
(2)								
(3)								
(4)	Estimation Method		Test Data HGP-A					Hawaii Geothermal Data

ATTACHMENT P-11

PUBLIC INTEREST

The proposed action, drilling of geothermal exploration wells, represents the initial phase of a project to explore for and develop geothermal resources in the Kilauea middle last rift zone, Puna District, Island of Hawaii. The application for a land-use permit for project development was approved in a Decision and Order by the Board of Land and Natural Resources on April 11, 1986, following a series of public hearings, public information meetings and five contested case hearings.

The environmental implications of all activities proposed related to the exploration and development of geothermal resources are described in comprehensive detail in the transcripts of the contested hearings and in the approved Revised Environmental Impact Statement (EIS) for Kahauale'a, June 1982, and the Supplemental EIS thereto, February 1986. No significant short-term or long-term adverse environmental effects of the proposed actions have been identified.

The issuance of a permit for authority to construct a geothermal well is considered to be in the public interest because of the State's objective of developing indigenous energy resources to reduce the State's significant reliance upon imported oil as its

GEOTHERMAL DEVELOPMENT ACTIVITIES

(Exploration Phase)

Kilauea Middle East Rift Zone

Puna District, Island of Hawaii

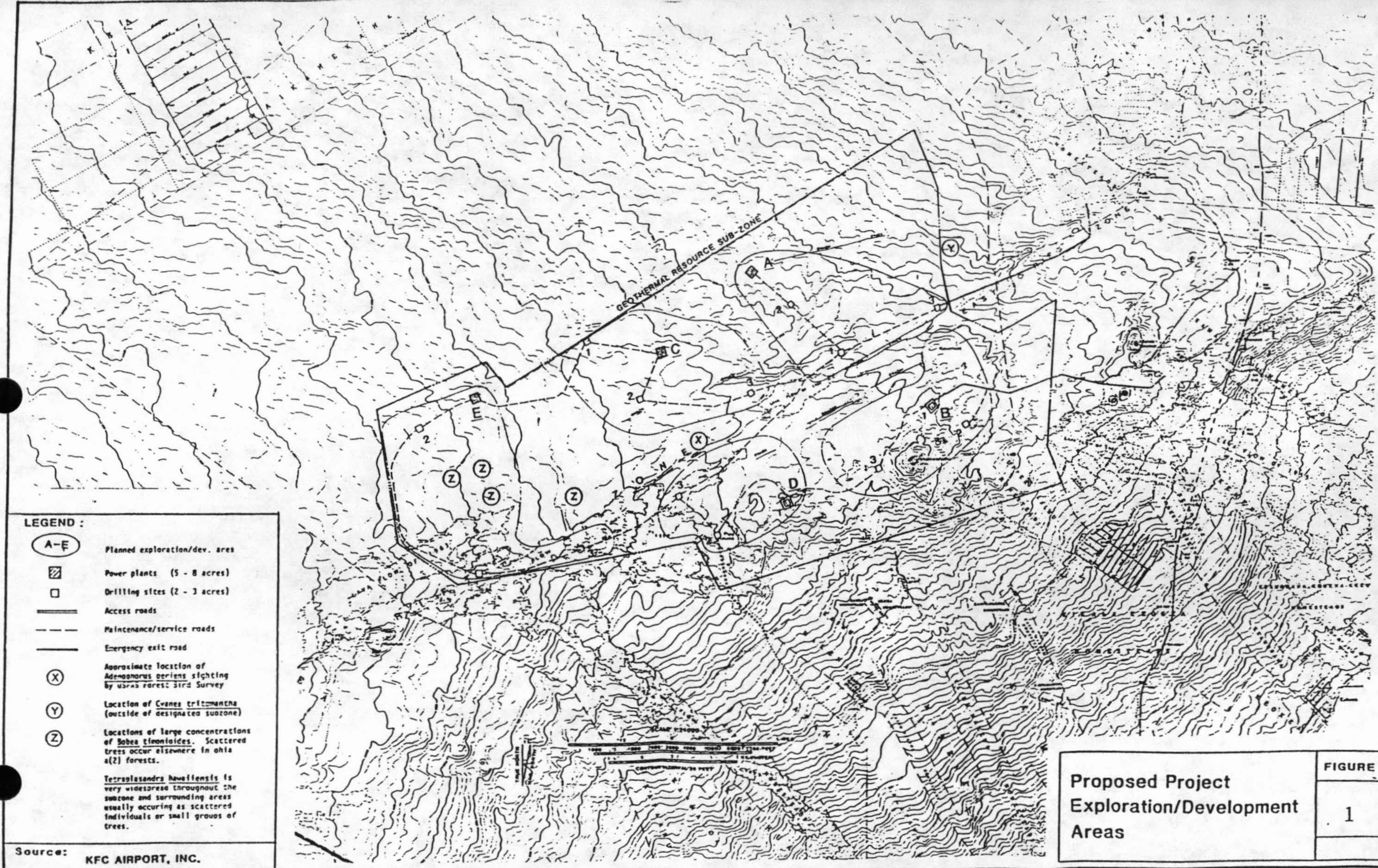
SUPPLEMENTAL DATA

for

AUTHORITY TO CONSTRUCT APPLICATION

1. Exploration Program
2. Well Drilling Program
3. Well Testing and Venting
4. H2S Emissions and Abatement System
5. Ambient Air Quality Impact Estimates
6. Application of BACT

Attachment 3
ATC Application



Proposed Project Exploration/Development Areas

FIGURE 1

6) After a resource discovery in any E/D area, two or more additional exploration wells may be drilled in that area before proceeding to the next area if there is a local demand for power requiring evidence of a proven resource sufficient to supply that demand.

Successful exploration wells would be shut-in after completion and testing if there is no immediate market for the resource.

Each well will require approximately 60 days of drilling to reach target bottom hole location, and five days for relocating the drill rig to another site. Drilling will be continuous. Drilling of the 12 wells that constitute the intial exploration phase of this project is expected to require two years. No time table can be projected for proceeding into the development phase.

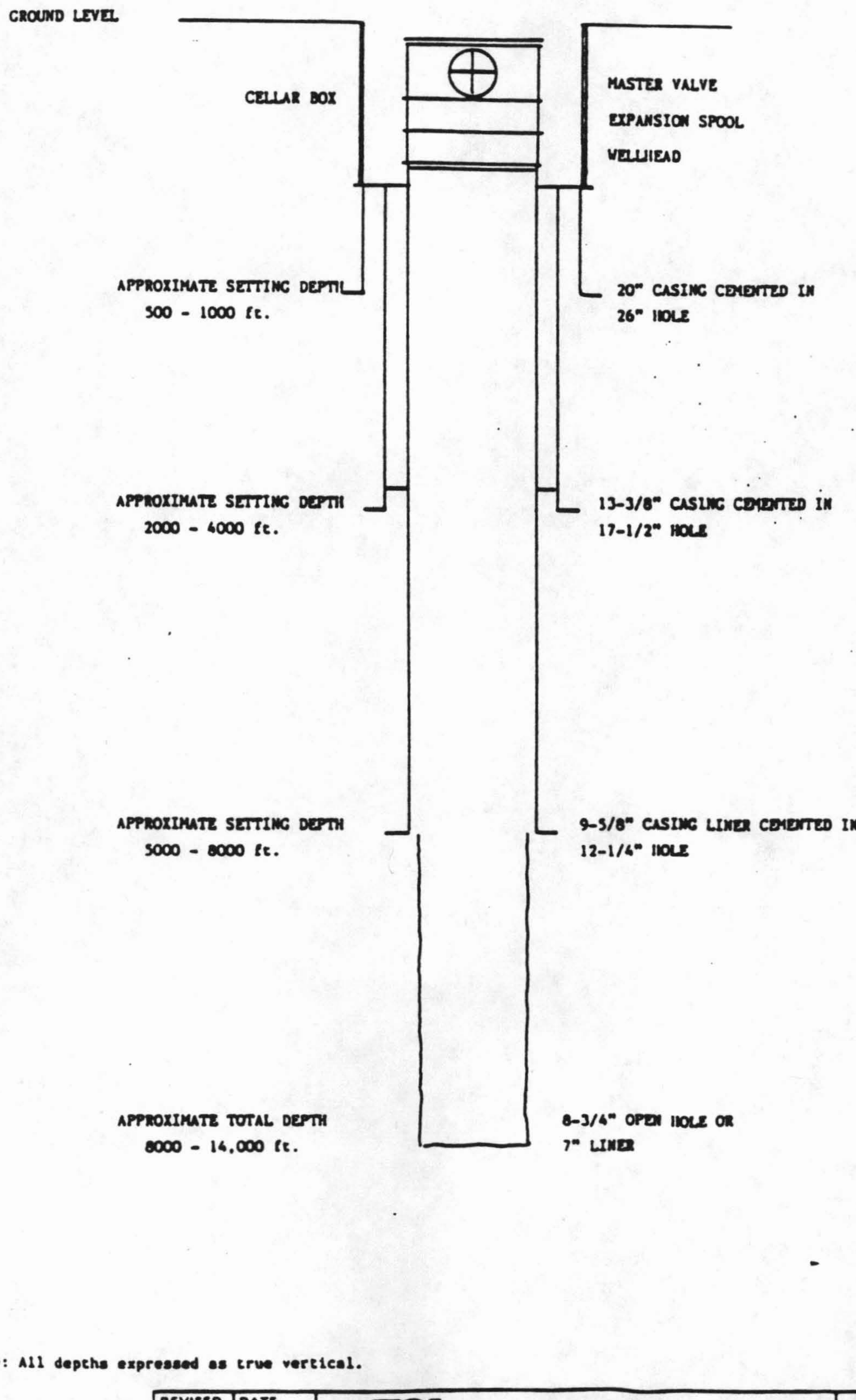
2. Drilling Program

Figure 2 depicts the typical geothermal well profile showing the dimensions of the well bore and drill pipe or casing, and the depths to which specific sized casing is installed. Conductor pipe (normally 26"-28" diameter) is the first string of pipe installed to a depth of 100 to 150 ft. in a hole of 36" diameter followed by:

(1) surface casing (20" diameter to 500-1000 ft. depth) set in a hole of 26" diameter,

(2) Intermediate casing (13 3/8" diameter to 2000-4000 ft. depth) set in a hole of 17 1/2" diameter,

(3) Intermediate casing (9 5/8" diameter to 5000-7000 ft. depth) set in a hole of 12 1/4" diameter),



Note: All depths expressed as true vertical.

REVISED	DATE	TSi ThermaSource Inc.	DRAWN
			FOR:
			BY:
		Figure 2	DATE:
		TYPICAL WELL PROFILE	SCALE:
		(True/Mid-Pacific Project)	DRAWING No.

(4) Production (slotted) liner if required (7" diameter to total depth set for commercial production) in a hole of 8 3/4" diameter.

Depending on the subsurface geology, it is planned to drill with air from the surface to total depth using two low stage compressors with 1,200 CFM and one high stage compressor for pressure up to 400 psi providing the formations drilled are compatible. Air drilling is most successful in hard rock where there is no influx of formation waters. When air drilling is not possible, mud drilling will be conducted using the optimum mud weights and viscosity to remove the cuttings from the formations drilled. Under normal drilling conditions, approximately 2,000 bbls/day of water will be required. However, most of the water will be recycled. A rain catchment system with a capacity of 900,000 gallons will be constructed as a supplemental source to meet total project water requirements.

All casings will be joined and cemented to assure the integrity of the well bore from surface to the producing interval. The objectives in cementing the casing are to completely "in-fill" the cased and open annuli to resist landsliding and groundwater movement and to anchor the casing sections to each other and to the ground. The cement sheath will protect the casing against possible corrosion by thermal brines and gases, prevent uncontrolled flow of thermal water and steam outside the casing, and minimize creep due to thermal expansion. The casing will be cemented using Type G cement from the bottom of casing to the surface in accordance with industry standards.

Each well will have a casing head installed on the surface casing; to this a master gate valve will be installed which will be left on the well. In addition, a hydraulically operated master gate valve with annular preventer will be installed as a component of the well head assembly. When air drilling is being conducted, a rotating head assembly will be installed for positive control.

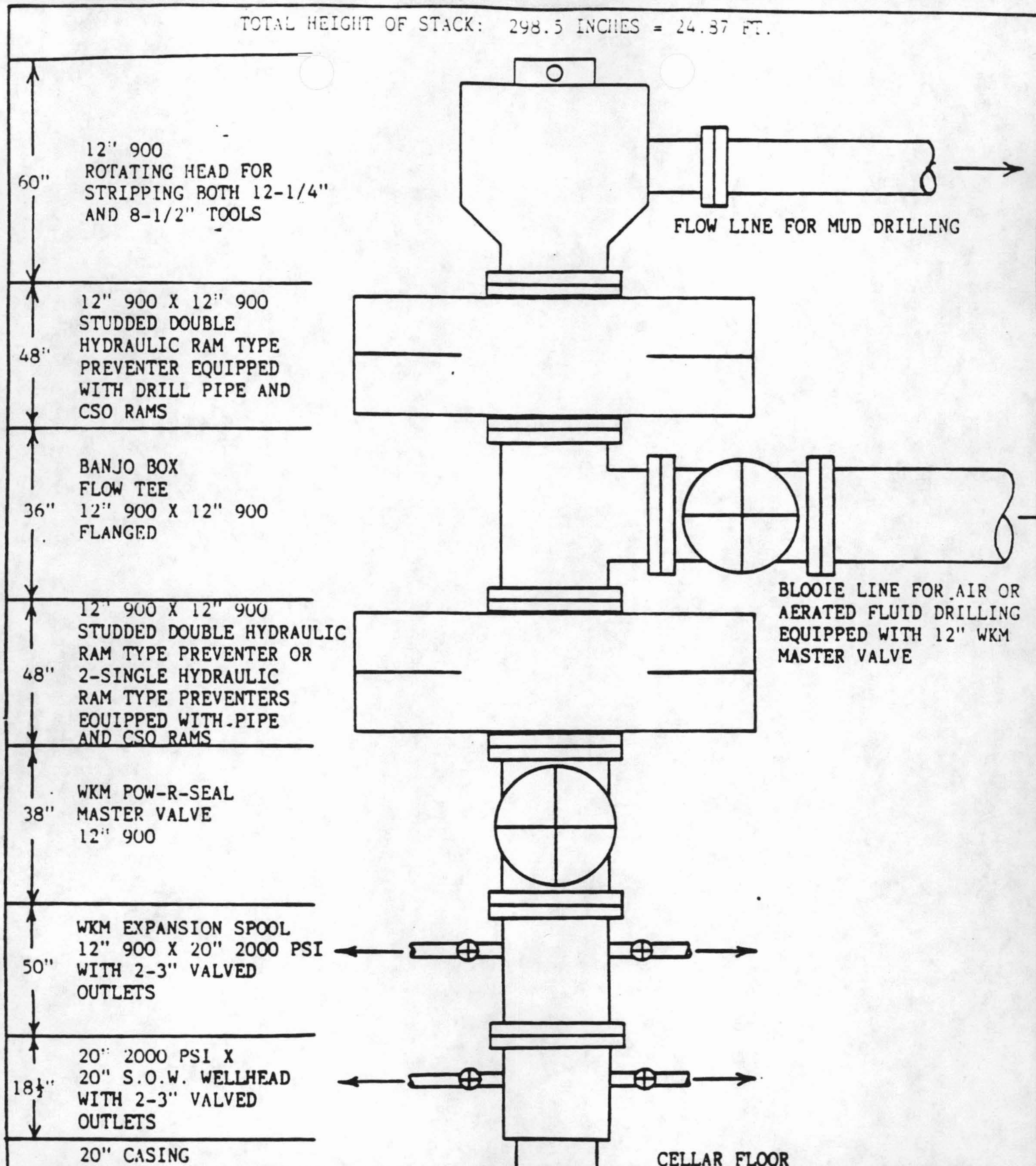
The following standard safety devices will be used to protect against a blowout from the well:

- 1 Double Gate preventer with CSO rams plus 4-1/2-inch drill pipe rams, 12-inch 900 series.
- 1 Annular Preventer 12-inch 900 series.
- 1 Rotating Head when air drilling.

A blowout prevention system is individually designed for each cemented casing string. Figure A-3 shows a typical blowout preventer system designed for high pressure wells.

While drilling, all data will be recorded in duplicate. All information will be logged by a well site geologist. Summary reports will be prepared upon completion of each well, as well as the standard well completion reports.

In the event it becomes necessary to abandon a well, the operator will analyze data from the logs to determine what geologic formations are required to be covered by cement. The plugging will be performed through open ended drill pipe using API Class G or equivalent, cement in accordance with industry standards. After the downhole plugging is complete, a cement plug will be



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BY:	LEC
DATE:	7/28/88
SCALE:	N/A
DRAWING No.	

TRUE MID-PACIFIC/GEOTHERMAL PROJECT
BLOW OUT PREVENTER STACK FOR 13-3/8" CASING
FIGURE 3

placed in the top of the surface casing, the casing is then cut off, and the area backfilled and restored.

3. Well Venting and Testing.

a. Well Venting.

Standard industry practice requires that successfully completed geothermal wells be vertically vented at full open flow to completely remove debris and rock particles from the well bore before the flow can be diverted to horizontal pipelines to a steam/water atmospheric separator for tests and abatement processes. Venting may occur for up to eight hours in segments or continuously. The wellflow can be controlled at the well head assembly with the master shut-off valves. The flow will exit a vertical pipe connected to the well bore. The full open flow rate of the well is not expected to exceed 220,000 lbs. of geothermal fluid per hour. The environmental impacts of venting are discussed in Paragraphs 4 & 5 below.

b. Flow Testing.

The purpose of flow testing each well is to determine whether characteristics of the geothermal reservoir and fluid are suitable for economic development as a source of electrical power.

Specifically, testing a geothermal hot water well should accomplish the following objectives:

(1) Evaluate the producing capabilities of the reservoir (aquifer). The well should be produced at or above pre-determined commercial rates to ensure representative samples of the geothermal resource. Surface measurements of mass flow, temperature, and pressure should be monitored.

Measuring bottomhole pressures (flowing and shut-in) with downhole recording gauges are desirable but not essential. This data will be used to estimate formation transmissivity, productivity index (PI), and formation damage.

(2) Determine properties of the produced fluids. This includes chemical composition, dissolved solids, pH, temperature, enthalpy, and pressure. This data will be helpful in making fluid comparisons between wells to determine aquifer continuity and to anticipate potential long term production problems.

(3) Estimate reservoir configuration. Ideally, a well test will provide estimates of long-term producing capability. Unfortunately, the duration of most well tests precludes such estimates unless the reservoir is very small. The well test should be conducted to sample a reasonable drainage area. If any boundaries are located within this area, the pressure buildup should detect it. If the producing formation is a fractured reservoir, then an indication of the well decline rate may be evaluated during a long-term test. Spinner surveys should be considered to determine where the fluids are entering the wellbore.

Testing of the wells will follow a procedure similar to the testing of the HGP-A well in Puna in which both noise and environmental pollution abatement were accomplished by use of a steam/water separator and rock muffler and the injection of caustic soda to limit emissions of hydrogen sulfide gas. Figure 4 is a schematic drawing of the flow test process. Tests will also be conducted on the integrity of the well to bottom hole through casing, logging of the cementing tests, and pressure testing.

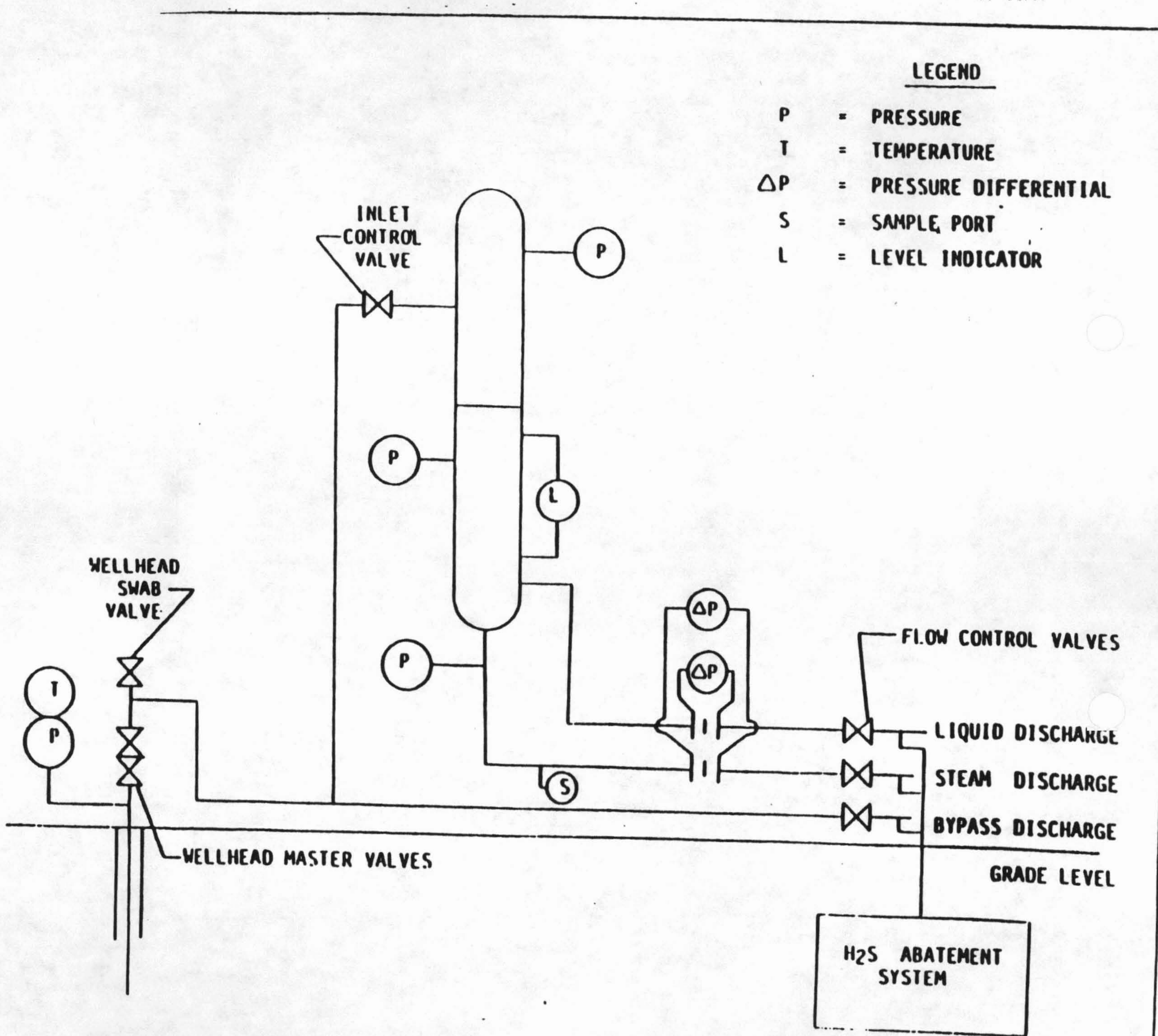

FIGURE 4

REVISED	DATE

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SHORT TERM FLOW TEST SYSTEM SCHEMATIC

DRAWN
FOR:
BY:
DATE:
SCALE: ~
DRAWING No.

Geothermal fluid flow during the production tests will flow to the well site sparging pit or the sump as appropriate. The project's environmental specialists will evaluate the reservoir fluids from each well and will consult with the appropriate regulatory agency to determine whether the fluid can be percolated into the ground or pond liners will be required. Due to the highly porous nature of the topsoil near surface formations, fluids should percolate readily into the ground. The chemistry of the well fluids are expected to be relatively benign, if similar to the HGP-A well, and should have no adverse impact on the basal water table at sea level due to the relatively low volume of fluid expected to flow from the well. In addition, the basal water table within the rift zone is expected to be non-potable. This supposition will be tested during the drilling of each well by sampling the ground water at the surface of the basal lens.

4. Source Emissions and Abatement Systems

a. The principal source of emissions during the construction of geothermal exploration wells is the geothermal fluid/steam released during the drilling, venting and flow testing of these wells. Tables 1 and 2 contain tabulated data on the concentrations of gases and disolved solids in the geothermal steam and brine. The princiapl pollutant in the geothermal fluid to be controlled is hydrogen sulfide.

b. Characteristics of H2S

Hydrogen sulfide, a colorless, acidic gas is toxic to humans and may be corrosive to metals including high strength steel. Drilling for geothermal resources in a hydrogen sulfide environment can be hazardous at and in the immediate vicinity of the drill site unless adequate safety precautions are taken.

NONCONDENSABLE GAS CONCENTRATIONS IN STEAM

Gas	Concentration in mg/kg (ppm/w)		
Carbon Dioxide	250	-	1,200
Hydrogen Sulfide	800	-	1,300
Argon	6	-	13
Nitrogen	10	-	700
Methane	1	-	
Helium	<0.009	-	
Hydrogen	11	-	14
Total	1,500	-	2,200

The above data are based on analyses of fluids from the HGP-A well, Kapoho State 1, Kapoho State 1A, and Kapoho State 2 wells.

Table 1

DISSOLVED SOLIDS IN GEOTHERMAL BRINE

Element	Concentration in mg/kg (ppm/w)		
Sodium	600	-	10,000
Potassium	123	-	2,700
Calcium	40	-	920
Magnesium	1	-	2
Iron	<1	-	8.4
Manganese	<1	-	8.5
Boron	4	-	11
Bromide	40	-	80
Iodide	<20	-	
Fluoride	0.2	-	0.9
Lithium	1	-	9
Chloride	925	-	10,000
Ammonia	<0.001	-	<0.05
Sulfate	9.2	-	24
Mercury	<0.001	-	<0.05
Arsenic	0.09	-	0.4
Silica	420	-	1,500
Total Dissolved Solids	2,500	-	35,000

Table 2

The sense of smell cannot be relied upon to indicate either the presence or the concentration of H_2S gas. At lower concentrations, the odor of rotten eggs can be detected. At higher concentrations, (at 100ppm or above) the sense of smell is impaired in two to fifteen minutes. Direct exposure to concentrations in the range of 500ppm to 1500ppmv in the absence of any mixing or dispersion in the atmosphere could cause collapse, unconsciousness and death. The Occupational Safety and Health Administration (OSHA) permissible exposure limit for an employee in an 8-hour work period is 10ppm with an excursion limit of 15ppm for 15 minutes during the 8-hour period. The proposed standard for H_2S exposure limit for the general public is a maximum ground level concentration of 0.1ppmv for 1 hour.

Appropriate safety measures are instituted by the operator to minimize the potential hazards to personnel from exposure to toxic levels of H_2S at or in the immediate vicinity of the drill site and to train personnel in emergency measures for accidents causing exposure to excessive levels of H_2S.
H_2S monitoring equipment including alarm systems will be placed at the drilling rig (rig floor and well-head cellar) and at various locations within the drilling site and along the access road at the entrance to the drilling site to detect the presence of H_2S from any natural venting in the rift zone and due to emissions from geothermal resources brought to the surface during or as a result of drilling operations.

c. Emissions and Abatement During Air Drilling

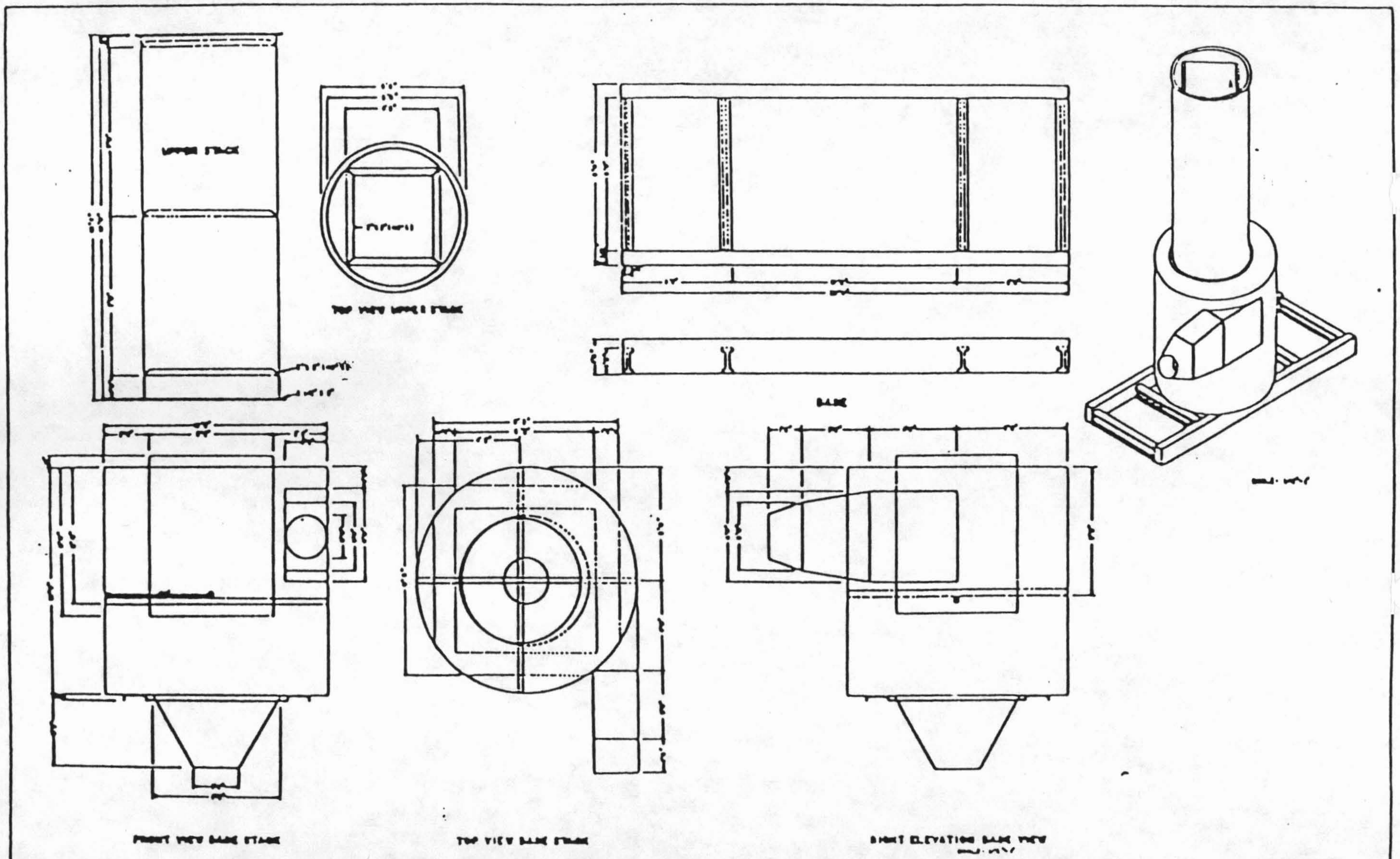
During drilling, it is estimated that geothermal fluids will not be encountered during the first forty days of drilling and no geothermal emissions will occur. During the last twenty days of drilling a progressively larger volume of geothermal steam will be produced until a maximum estimated volume of 50,000 kg/hour of steam and 50,000 kg/hr of brine will be generated by the well.

During drilling with air, a tangential muffler/atmospheric separator, (Figure 5), is used to control noise and effluent (air exhaust, steam/water, drill particles) from the well bore. This muffler/separator consists of a large diameter chamber, 10' diameter by 10' tall, with a 6' diameter stack that extends 16' feet above the 10' chamber. The principle behind this type of device is that the discharge from the well (ambient air circulated downhole and/or steam/water produced from the well) will enter the large diameter chamber tangentially and flow around the chamber, throwing out drilled particles to the side due to centrifugal force in the high velocity air and/or steam exhausted to it. These particles then fall out of the funnel-type structure located at the bottom of the muffler/separator and are channeled to the disposal sump. The air and/or steam must then go down in the chamber to enter the exit stack, the bottom of which sits below the tangential entrance, to be emitted to the atmosphere. The actual blooie line, i.e., the piece of pipe that connects the wellhead and muffler/separator, typically is a piece of 13-3/8" O.D. casing which gradually expands to 36" O.D. and then to a rectangle of a larger cross sectional area than the 36" O.D. pipe. The purpose of this gradual increase is to allow the air and/or steam to expand slowly so as to decrease the noise as much as possible. Water may also be injected, at rates of 60 to 100 gallons/minute, into the muffler/separator as well as the blooie line. The mixing of water with the air/steam exhaust allows some cooling of the steam which aids in noise reduction.

It is estimated that no more than 2% of the brine (as aerosol droplets) will escape from the cyclone separator described in Figure 5, and that the steam will have a hydrogen sulfide concentration of approximately 1,100 mg/kg (1,300 mg/kg in the reservoir fluid less 15% dilution by water added to the air drilling system). This results in an unabated emission rate of 20 kg/hr of brine aerosol particulate and 55 kg/hr of hydrogen sulfide.

From an environmental perspective, air quality regulations limit the amount of H_2S emissions during drilling operations to 8.5 lbs/hr., or .025ppmv. During drilling, it is expected that geothermal resources, whether vapor or liquid dominated, will be encountered at depths beginning at 3,000 ft., more or less, below sea level. H_2S is expected to be present in the geothermal resource as a non-condensable gas in concentration levels between 1000ppm-1300ppm based on the characteristics of the resource discovered in the lower east rift of Kilauea.

Hydrogen sulfide concentrations in the steam flow through the well bore to the steam/water separator will be monitored continuously during air drilling operations by on-site well loggers using an interference-free H_2S detector, with periodic back-up wet chemical testing. Continuous monitoring and recording of the H_2S concentration in the blooie line (steel pipe leading from the well head to the atmospheric separator) will be accomplished by use of a lead acetate tape instrument and a recorder. The data recorded will alert



MUFFLER AND DUST SEPARATOR

FIGURE 5

personnel when H_2S concentration levels in the steam flow require mass emission rate calculations to determine the need to activate and operate the H_2S abatement system. The injection of sodium hydroxide (NaOH)) into the blooie line steam flow in proper proportions and amounts will enable the logger to maintain emission rates at or below the H_2S emission limit of 8.5 lbs/hr. A sodium hydroxide treatment mole ratio of 4 to 1 ($NaOH/H_2S$) will be used initially. The optimum mole ratios will be determined during abatement operations and adjusted as necessary. During drilling, residual H_2S from the steam flow following abatement will be released to the atmosphere through the atmospheric separator. The abatement process is completed in the 2 to 3 seconds the steam flows from the well head through the blooie line to the outlet of the atmospheric separator. The desired level of abatement is achieved by adjusting the ratio of $NaOH/H_2S$.

Permanent records will be maintained as follows:

(1) The concentration of H_2S in ppm (volume) and ppm (weight) upstream of injection ports,

(2) Injection rates of NaOH

(3) Amount and type of chemicals on site

(4) Results of wet chemical test

Emissions of particulates from air drilling will be controlled by water injection in the blooie line.

(When drilling with mud, H_2S emissions are not expected to be detectable since the mud will prevent discharge of pollutants from the well bore.)

d. Emissions During Venting

Geothermal brine, brine aerosol particulates and hydrogen sulfide will be discharged to the atmosphere during venting of each well. Assuming a total of eight hours of venting the aerosol emissions would amount to 1,000 kg/hr of particulate and the hydrogen sulfide emissions would amount to 55 kg/hr. No emission abatement system is used during the venting process.

e. Emissions During Flow Testing

Emission abatement controls will be applied during flow testing of the geothermal well. A rock muffler system will be installed on the steam discharge side of the cyclone separator used for conducting the test. Injection of NaOH into the steam line upstream of the rock muffler will be done at a level that will allow the hydrogen sulfide present in the steam phase to be abated down to no more than 8.5 lbs/hr as required by 11-60-15. Abatement levels of 95% have been achieved at the HGP-A well using a system of this design. (Without abatement, the maximum emission levels from the flow test would be equivalent to those for venting. Emission levels would be reduced in proportion to the test flow rate.)

5. Ambient Air Quality Impact Estimates

The dispersion modelling that has been performed for the proposed geothermal development project in the Kilauea middle east rift by meterological consultants (Daniels & Schroeder) estimated the impacts of source emissions from those project operations that have the potential to threaten or violate air quality standards: a 55-mw power plant in operation and steam stacking from a rock muffler. The results of this analysis using EPA Gaussian diffusion models indicated that proposed ambient air quality standards for hydrogen sulfide (H2S), as well as the maximum allowable increase in H2S concentration in the ambient air above the natural background level, wouTd not be exceeded. (See Tables 2 and 3 in the diffusion modelling report, Tab A.)

Because the EPA Gaussian model yields ambient air concentration estimates that are linear with respect to the rate of emission of hydrogen sulfide, the existing anlysis for power plant operation and stacking emissions can be used to estimate the ambient air concentrations associated with the drilling operations. Since emission release conditions during drilling will be most similar to those occurring during stacking of power plant emissions, the results of the previous analysis on emissions during stacking will be used in the linear extrapolation to estimate impacts of emissions during drilling.

In Table 1, of the Daniels and Schroeder analysis, the release temperature of emissions was 373°K; the emissions from the drill pad cyclone separator during drilling and testing will have the same release temperature as for stacking. The emission velocities of the steam discharge from drilling and testing are expected to be lower than those used in the Daniels and Schroeder analysis for stacking. Steam discharge velocities will equal 10 m/sec and 3 m/sec for drilling and testing, respectively, and the stack heights will be 5m and 2m, respectively. The hydrogen sulfide emission rates used for estimating impacts of plant emissions during stacking are, however, approximately three times those that will occur during drilling and testing: 3.1 grams per second from the plant stacking versus a maximum of 1.07 grams per second from drilling and testing.

Because concentrations of hydrogen sulfide downwind of the emissions source (geothermal well) are much more sensitive to the emission rate than to stack height and emission velocity of the source, the estimated maximum ambient concentrations of H2S due to drilling and testing of a single geothermal well are expected to be well below the maximum concentrations that could occur due to power plant operations and stacking (for a 55-mw plant) as estimated in Tables 2 and 3 in the Schroeder and Daniels model and will approximate those shown in Table 1, Figure 6. The estimated maximum concentrations for venting are shown in Table 2 of Figure 6.

Well venting will, however, produce approximately 16.4 grams of hydrogen sulfide per second. This emission rate could generate ambient air concentrations of hydrogen sulfide at the property boundary in excess of the proposed allowable maximum increase in the ambient air over the background level for four to eight hours if well venting is conducted during certain neutral or stable wind conditions. For that reason, well venting will be conducted only during periods of favorable wind conditions. Modelling of the downwind ambient air hydrogen sulfide levels during venting under unstable conditions (Kahaualea EIS pp. 5-27 to 5-28) yields a maximum expected concentration of 15.5 ppb at one mile downwind of the geothermal well which would be well within the proposed allowable increment at the property boundary.

MAXIMUM ESTIMATED CONCENTRATIONS OF HYDROGEN SULFIDE FROM A GEOTHERMAL EXPLORATION WELL

(Based on Linear Extrapolations From EPA Gaussian Diffusion Model NOAA (1983)

Distance (Miles)	Stability Class	Wind Speed MPS	Concentration ppb
Table 1 - Drilling & Testing			
0.5	Neutral	20	1.38
1.0	Neutral	15	0.864
1.5	Neutral	10	0.657
2.0	Stable	5	0.484
2.5	Stable	3	0.553
Table 2 - Venting			
0.5	Neutral	20	19.71
1.0	Neutral	10	12.32
1.5	Neutral	10	9.36
2.0	Neutral	10	6.9
2.5	Stable	3	7.89

FIGURE 6

6. Application of BACT Criteria to Emission Sources for Geothermal Exploration Drilling

A. Well Drilling

Current industry-wide practice in the drilling of geothermal wells uses drilling mud or compressed air depending on the type of geology encountered and whether there is influx of formation waters.

Drilling mud with its density and pressure will prevent geothermal fluids from flowing up the well bore with the cuttings which would result in the lowest achievable emission rate (LAER) when it is used. Thus, the use of drilling mud is BACT when this type of drilling is appropriate. In drilling with air, the cuttings and the steam fraction of geothermal fluids (when encountered) would be carried up the annulus of the well bore with the compressed air. In this system, the geothermal steam is mixed with air in the well bore and chemically treated with NAOH at the surface before it is directed into the atmospheric separator for discharge to the atmosphere. The H2S abatement system for drilling with air is identical to that used during flow testing of the well. This system is the BACT for well drilling with air.

B. Flow Testing

During the flow testing of a successfully completed geothermal well at a stabilized flow rate, the liquid and vapor phases are separated by use of a steam/water separator unit in order to accurately determine the liquid and vapor fractions. The mass flow of each phase is measured after which the steam phase discharge is directed to the rock muffler. The abatement system (portable chemical injection unit) is installed up-stream of the rock muffler as shown in Figure 4. The injection process is described in Paragraph 4 above.

Industry-wide experience indicates that 95% or more of the H2S in the vapor phase can be scrubbed with the injection of sodium hydroxide (NAOH). This process is the BACT for flow testing.

C. Well Venting

As described in Paragraph 2, well venting at full, open flow is required to clear the well bore of debris after drilling is completed. Because of the high velocity and temperature of the flow with entrained rock particles, it is not feasible to divert the flow to a spearator and inject chemicals to abate emission of the H2S present in the steam fraction of the flow before discharge to the atmosphere. However, under suitable meterological conditions (unstable), the downwind concentration of H2S can be significantly reduced due to the mixing with air so that the concentration level at the property boundary would be within the state AAQ standard. Therefore, BACT for well venting will be to vent wells during meterological conditions that will allow standards to be maintained.

ESTIMATES OF AIR QUALITY FOR THE WAO KELE GEOTHERMAL PROJECT

prepared for

True/Mid-Pacific Geothermal, Inc

by

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DECEMBER 9, 1985

TAB A

I. Wind conditions.

In order to asses the potential impact of the proposed geothermal development we investigated a number of meteorological situations which could generate high concentrations. These situations can be divided into two categories:

a. Situations with a mean wind direction prevailing throughout the period.

b. Situations with stagnating air for several hours i.e. periods without a distinct mean wind direction.

The first category comprises simple advection situations which were modelled using an EPA (NOAA 1983) recommended model.

For the second category we used a non-EPA model as no appropriate model for this situation was readily available from the EPA. This model is only a puff model variant of the continuous source model used for the first category.

Calculations were made for a 55 MW plant emitting 150 gr/MWhour or 2.3 gr/sec of hydrogen sulfide during operations and 3.1 gr/sec during stacking. Other plant characteristics used as listed in Table 1 below are taken from a Dames and Moore report to the EPA (1984) except for the cooling tower exit velocity temperature where a more conservative value recommended by D. Thomas (1985) was used.

Table 1. Emission characteristics for a proposed 55 MW plant.

Operation	Emission rate gr/sec	Release height m	Release temp. K	Release radius m	Release velocity mps
Stacking Rock muffler	3.1	9.8	373	1.05	29.5
Power prod. Cooling tower	2.3	16.8	311	4.20	8.3

Only hydrogen sulfide emissions from power plant operation and stacking are included in our assessment as these are most likely operations to potentially violate proposed State of Hawaii ambient air quality standards.

II. Situations with a distinct mean wind.

The commonly used and EPA recommended Gaussian diffusion model for a continuous source was used to estimate concentrations for situations with a distinct mean wind direction.

Assuming no surface reflection of pollutants this model estimates center line or maximum concentrations in gr/cum at a distance x m downwind of a plant emitting E gr/sec with a mean wind speed U mps as:

C = E exp(- H*H/sigz(x)/sigz(x)/2)/(2*Pi*sigz(x)*sigy(x)*U)

where sigz(x) is the spread in the vertical plane and sigy(x) that in the horizontal cross wind plane, Pi is 3.14 and H is the effective stack height.

The effective stack height is the sum of the physical stack height, given in Table 1, and the plume rise due to buoyancy and momentum of the released gases as they exit the cooling tower.

The plume rise was calculated from Brigg's expressions as given in the NOAA (1983) report used. For the ambient temperature a night time value of 73F were used based on temperature records from nearby Mountain View.

The wind speed affects the estimated concentrations in two ways:

* low winds produce poor initial mixing but allow emissions to be lifted to several times the physical stack height,

* high winds provide large initial mixing but prevent emission rising far prior to loosing vertical momentum.

Because of the plume rise expressions it was not convenient to directly determine maximum downwind concentrations. The Gaussian diffusion expression was instead calculated for every half mile downwind of the source between 0.5 and 3.5 miles for wind speeds between 1 and 30 mps and for the seven stability classes used by the

EPA. Horizontal and vertical standard deviation expressions (sigy(x) and sigz(x)) were taken from the NOAA (1983) report.

Table 2 gives the highest concentrations found at the different distances used with the corresponding stability class, wind speed and effective stack height for the two types of emissions.

Table 2. Maximum calculated concentrations of hydrogen sulfide from a 55 MW plant for five downwind distances.

Distance mile	Stablilty class	Wind speed mps	Eff.stack height, m	Concentration ppb
Power production				
0.5	Neutral	20	37	4.2
1.0	Neutral	10	58	3.0
1.5	Neutral	10	58	2.4
2.0	Neutral	10	58	1.8
2.5	Stable	3	94	2.0
Stacking				
0.5	Neutral	20	33	4.0
1.0	Neutral	15	41	2.5
1.5	Neutral	10	56	1.9
2.0	Stable	5	79	1.4
2.5	Stable	3	92	1.6

As stated previously the program performed calculations only at five selected distances with maximum concentrations occurring somewhere in between. These maxima are however only a few percent higher than values listed above and well within the precision of the estimates. As can be seen maximum concentrations occurred within the distance range used.

Downwash of pollutants behind the cooling tower can occur during unstable conditions but will not cause high concentrations beyond property lines as the closest tower will be more than one mile from the boundaries.

In the Dames and Moore (1984) report to the EPA considerably higher concentrations were estimated using EPA models (MPTER and COMPLEX). These maxima occurred however with receptors located at elevations higher than the source and assuming that the pollutants did not follow the terrain contours but rather continued in a horizontal line to the receptor.

While this situation can occur in a valley during stable conditions with a source at the bottom and receptors along its sides, we can not visualize a situation at the proposed geothermal area where this could happen. During drainage winds the pollutants will rise relative to the terrain as more cold air is produced at the ground while during trade winds and konas, stable conditions will not occur.

The above calculations depend critically on the estimated plume rise calculated from Brigg's expressions (NOAA, 1983). As these are empirically established, widely used and generally accepted, we see no reason not to use them though they were not specifically developed for the emission types dealt with in this report, especially as to our knowledge no other specific expressions are available.

We therefore conclude that for the proposed 55 MW plant downwind concentrations will not exceed 5 ppb beyond the property boundary during power plant operations or stacking when a discrete mean wind direction prevails.

III. Stagnating wind conditions.

The best available long term wind station to represent the area during stagnant wind conditions is the HGP-A site. As local wind condition can vary significant during stagnation periods, we used wind data from two sites near the area ,sites 21 and 22 (Fig. 1) where a monitoring station operated for limited periods during early 1985. In these data we identified one period at site 22 and four at site 21 when little or no wind prevailed for four to eight hours during night time periods.

Unfortunately the instruments at HGP-A malfunctioned during three of the four events at site 21 which thus leaves one occasion at each site for comparison. Fig. 2

shows a time plot of wind directions for these occasions for the sites and HGP-A.

The direction patterns in these plots reveal the feature- that caused the stagnation - the night time front that forms between the westerly drainage winds and the easterly trades.

Analysis of the site 21 events indicated that the drainage front was stalled by unusually strong trade winds which were also from a more northerly direction than usual. Site 21 lies on the north flank of the rift therefore the northeasterly flow retards the drainage.

At the front the air movements are small probably up to the top of the drainage wind layer at a few hundred feet. Thus the low winds measured at 30 ft at the sites could well extend to at least up to the effective emission heights given in Table 3.

The drainage winds are generally strong enough to push the front considerably east of the area except during strong trades. Based on an analysis of of open ocean winds from weather charts (U.S. Navy, 1958) we estimate that these conditions occur on an average six days per year.

We consider the case at site 21 (March 9 - 10, 1985) to be the worst scenario and base our air quality calculations for stagnation conditions on this period.

The plant characteristics in Table 1 were used for these calculations as well. Calculations were made for every mile from one to six miles. A night time temperature of 70F was used.

As concentrations resulting from stacking were always lower than those from power plant operations (Table 2), only this type of emission was this time included in the calculations.

With cold drainage flow submerging the site, stability condition class E (stable) in the Pasquill-Gifford classification (Pasquill, 1974) was used. Though there is a more stable class, F, the plume rise is considerably higher for this class than class E. Therefore in order to be more conservative, class E, which gives higher concentrations was used.

As in the previously analyses for non-stagnant conditions, the commonly accepted Gaussian diffusion model was used. No surface reflection was again assumed as it seems likely that pollutants trapped in the vegetation layer will not be refloated under the modelled wind conditions.

During nights with the stagnating front near the site, the air will probably not flow in a steady direction but will rather move back and forth with a low mean speed. The dispersion of pollutants from the plant under these conditions can be approximated by a series of smoke puffs which can be modelled using the Gaussian puff model.

The Gaussian puff model estimates the ground level concentration in gr/cum at time t seconds from a source emitting an amount E grams at time zero at a height H m at a distance x m from the receptor as:

$$C = E * \exp\left(-\left(H/sigz(t) + dx/sigx(t) \right)^{2} /2\right)/(2*PI)^{1.5}$$

$$/ \left(sigx(t) * sigy(t) * sigz*(t) \right)$$

where sigx(t) is the downwind spread and dx the downwind distance between the receptor and the center of the puff.

This model requires the knowledge of the smoke spread in three dimensions as functions of time which are not readily available.

Such expressions are however available as functions of travelled distance. These expressions were modified and used in the calculations. For the spread in the vertical and horizontal directions, sigz(x) and sigy(x), curves from Turner's Workbook (1969) as expressed mathematically in NOAA Tech. Memo (1983) were used. For the spread in the wind direction, sigx(x), curves developed by the U.S. Army (Beal, 1971) were adopted.

To convert these expressions into the time domain requires an assumption of the wind speed. Pasquill (1974) recommends the E stability class for wind speeds between 2 and 3 mps. Assuming a mean wind speed of 1 mps (0.5 mph), 2 mps (0.9 mph) and 3 mps (1.3 mps), the expressions were converted to give the spread as a function of time.

The calculations assumed that every 30 second a puff was emitted containing 2.3*30 gr or about 70 gr of hydrogen sulfide. The puffs were then allowed to sit at the effective emission height at the site and expand for four and eight hours according to the above expression. The position of the centers did not change during this time.

Each puff was then moved at a mean speed of 1 mph until its center was right above the receptor. The ground level concentration at the receptor, as caused by this puff, was calculated.

The procedure was repeated until all the puffs - 480 puffs for the 4 hour stagnation case and 960 for the eight hour case - had affected the receptor.

The puff centers were then allowed to move 40 meters downwind of the site and a new set of concentrations were calculated which thus represented the conditions about 90 seconds -later.

This procedure was repeated until one hour had passed at which time the puff centers were one mile downwind of the receptor. At this time, the average concentration during the preceding hour was calculated.

The effectve stack height was 148 m for the 1 mps case, 121 m for the 2 mps case and 108 m for the 3 mps case.

Table 3 below gives maximum concentrations for each downwind distance and period of stagnation with corresponding wind speed.

Table 3. Estimated concentrations of hydrogen sulfide downwind of a 55 MW plant emitting 150 gr/MWhr caused by a build up during stagnation periods.

Downwind distance miles	Duration of stagnation hours	Wind speed during stagn., mps	Concentration ppb
1	4	3	8.4
2	4	3	8.3
3	4	2	7.6
4	4	2	6.7
5	4	2	5.7
6	4	2	4.8
1	8	2	10.6
2	8	2	10.6
3	8	2	9.8
4	8	1	8.7
5	8	1	8.0
6	8	1	7.1

To the numbers in this table must be added the concentrations originating during the period of a distinct mean wind which prevailed when above puff concentrations would have been monitored.

These additive concentrations are less than those given in Table 2 as they would occur during a more stable conditions.

We therefore do not think that concentrations above 15 ppb would ever occur even during stagnant conditions from a 55 MW power plant located more than one mile from the property line either during power plant operation or stacking.

Even in the very unlikely case that the emissions from two 55 MW plants would be in line with each other and the receptor after an eight hour period of stagnation would the concentrations exceed 30 ppb, the recommended hydrogen sulfide standard for Hawaii.

VI. Conclusions.

We conclude that, based on our analyses, at least up to 110 MW of geothermal power can be produced in the proposed area without violation the proposed hydrogen sulfide standard of 30 ppb above background.

This analysis is based on models and parameters developed for a different environment and it should therefore not be a substitute for actual measurements.

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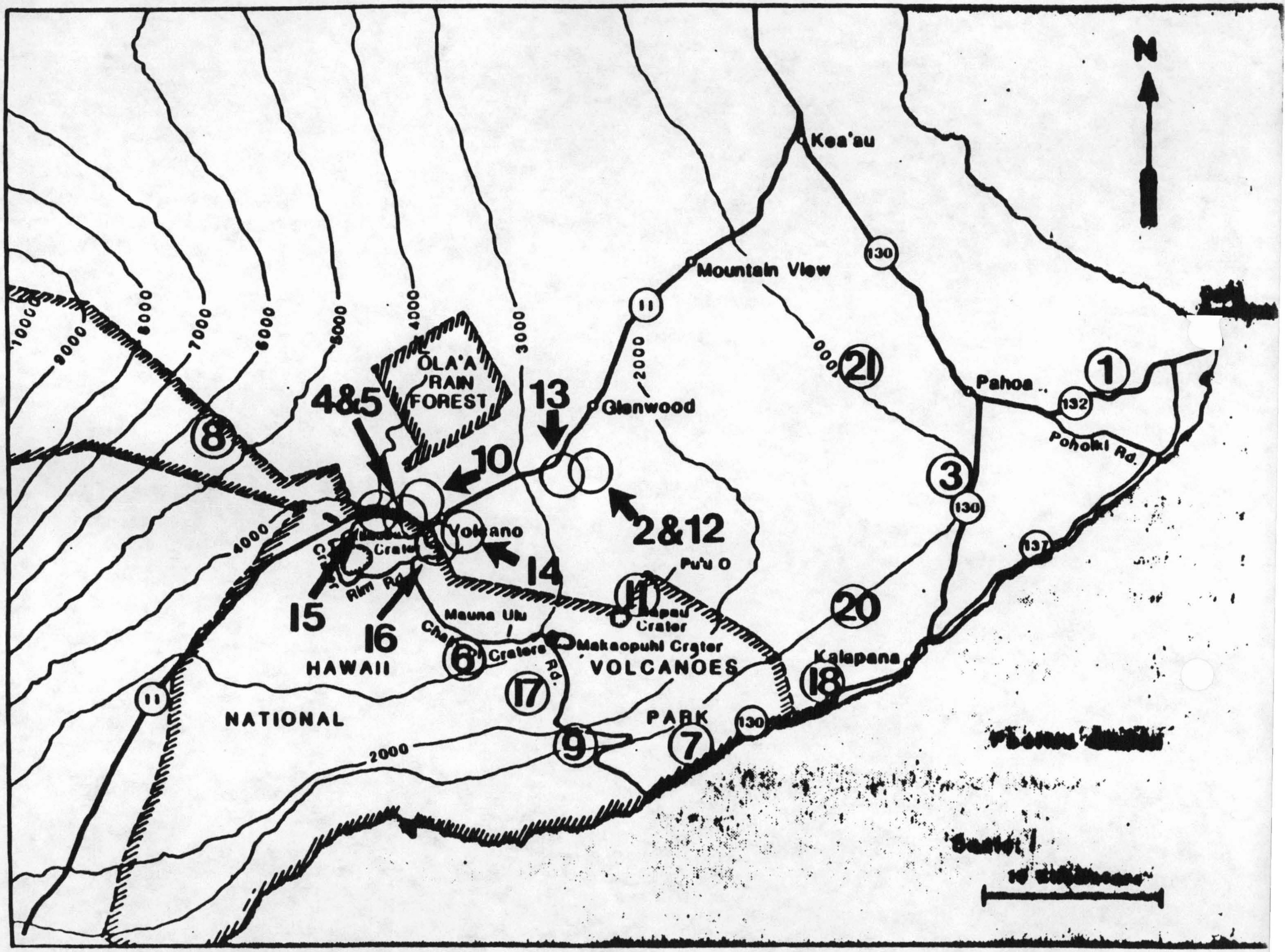
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Pohoiki Rd.
137
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RAIN
FOREST
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14
Volcano
Crater
Rim Rd
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16
Pu'u O
Crater
Mauna Ulu
Craters
Makaopuhi Crater
Rd.
HAWAII
VOLCANOES
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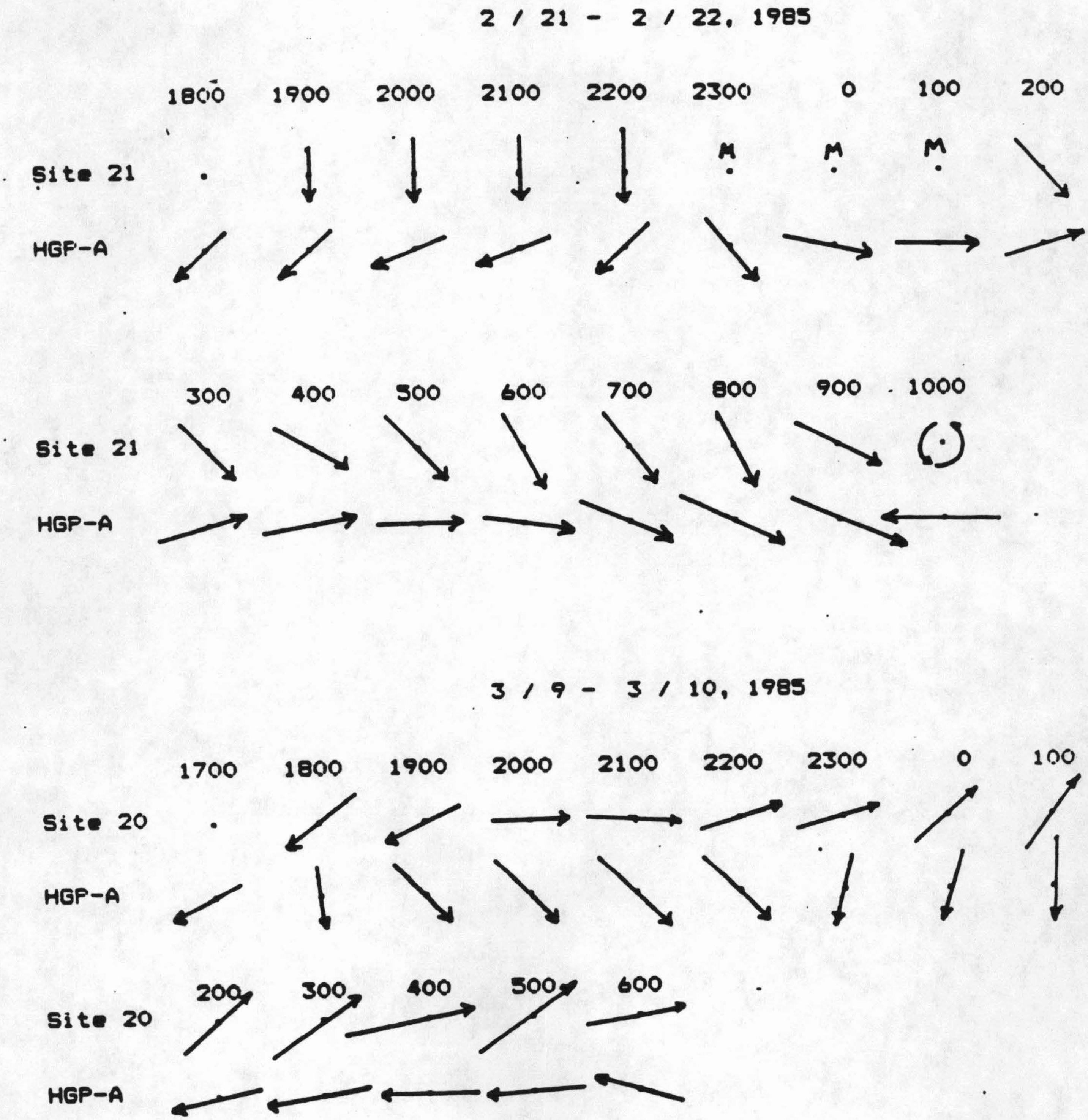

Fig. 2. Wind vectors for two adverse wind conditions at at sites 20, 21 and HGP-A.

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ATTACHMENT 4
ATC Application